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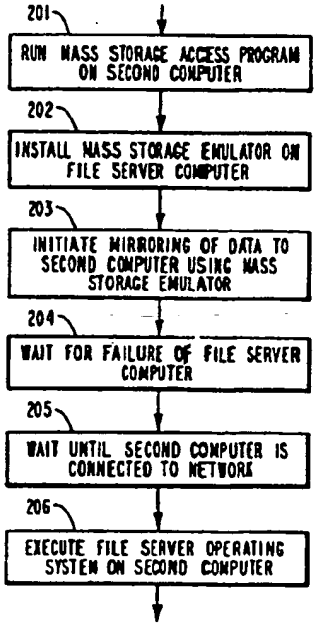
(54) Title: METHOD FOR RAPID RECOVERY FROM A NETWORK FILE SERVER FAILURE

(57) Abstract

A method for providing rapid recovery from a network file server failure through the use of a backup computer system. Unlike other redundant file server configurations, this method does not require the backup computer system to be running the file server operating system. Instead, it runs a special mass storage access program (201) that communicates with a mass storage emulator program on the network file server (202), making the disks (or other mass storage devices) on the backup computer system appear like they were disks on the file server computer. By mirroring data by writing to both the mass storage of the file server and through the mass storage emulator and mass storage access program to the disks on the backup computer, a copy of the data on the file server computer is made (203). In the event of failure of the file server computer (204), the backup computer can be restarted as a file server (205), using the copy on its disks. The same method can be utilized to restore normal system operation when the failure has been corrected.



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METHOD FOR RAPID RECOVERY FROM A NETWORK FILE SERVER FAILURE

Microfiche Appendix

This specification includes a MICROFICHE APPENDIX which is intended to be a part of the disclosure herein. The MICROFICHE APPENDIX contains 1 page of microfiche and a total of 69 frames. The MICROFICHE APPENDIX includes computer source code used in the implementation of one preferred embodiment of the invention.

Background of the Invention

Field of the Invention. This invention relates to network file server computer systems, and in particular to the methods used to recover from a computer failure in a system with a plurality of computer systems, each with its own mass storage devices.

Description of Related Art. It is often desirable to provide continuous operation of computer

systems, particularly file servers which support a number of user workstations or personal computers. To achieve this continuous operation, it is necessary for the computer system to be tolerant of software and hardware problems or faults. This is generally done by having redundant computers and mass storage devices, such that a backup computer or disk drive is immediately available to take over in the event of a fault.

A number of techniques for implementing a fault-tolerant computer system are described in Major et al., United States Patent 5,157,663 (which is hereby incorporated by reference in its entirety) and its cited references. In particular, the invention of Major provides a redundant network file server capable of recovering from the failure of either the computer or the mass storage device of one of the file servers. The file server operating system is run on each computer system in the network file server, with each computer system cooperating to produce the redundant network file server. This technique has been used by Novell to

implement its SFT-III fault-tolerant file server product.

There are a number of reasons why the use of a redundant network file server such as that described in Major may be undesirable. As can be seen from the description in Major, the software needed to provide such a redundant network file server is considerably more complex than the software of the present invention. This can result in a lower reliability due the increased presence of programming errors ("bugs") in the complex software. Also, the processing time required to handle a client request may be increased by the complexity of the redundant network file server software, when compared to a single-processor network file server. Finally, license restrictions or other limitations may make it infeasible or uneconomical to run a redundant network file server instead of a normal network file server.

Summary of the Invention

It is an object of this invention to provide rapid recovery from a network file server failure without the complex software of a redundant network file server. This is achieved by having a second, backup computer system with its own mass storage device (generally a magnetic disk). This backup computer is connected by an appropriate means for communications to the file server computer, allowing the transmission of information (such as commands and data) between the two computers. A mass storage emulator, running like a device driver on the file server computer, sends information to a mass storage access program on the backup computer. The mass storage access program performs the requested operation (read, write, etc.) on the mass storage system connected to the backup computer, and returns the result to the mass storage emulator on the file server computer.

This makes the mass storage device on the backup computer look like another mass storage device on the file server computer. The data mirroring option of the file server operating system can be

activated (or, if the operating system does not support data mirroring, a special device driver that provides data mirroring can be used), so that a copy of all data written to the mass storage device directly connected to the file server will also be written to the mass storage device on the backup computer, through the mass storage emulator and mass storage access programs.

When a failure is detected in the file server computer system, the backup computer can be restarted as a file server computer. The mass storage device of the backup computer will contain a copy of the information on the mass storage device of the failed file server, so the new file server can start with approximately the same data as when the previous file server failed.

It is a further object of this invention to improve the reliability of a redundant network file server computer system by reducing the complexity of the software when compared to the software of a redundant network file server. As will be clear from the discussion of the preferred embodiment of

the invention, the programs for the mass storage emulator on the file server computer and the mass storage access on the backup computer are considerably less complex than a full redundant file server operating system.

It is a further object of this invention to improve the performance of a network file server by improving the performance of the mass storage used by the network file server. Because of the simplicity of the mass storage emulator and the mass storage access program, as well as the fact that the backup computer is only running the mass storage access program and not a file server operating system that must also handle network requests and other activity, the performance of the emulated mass storage device may exceed the performance of a mass storage device directly attached to the file server computer. This is particularly true if the mass storage access program is expanded to provide caching of information and the full memory of the backup computer (less that occupied by a simple operating

system and the mass storage access program) is used as a cache.

These and other features of the invention will be more readily understood upon consideration of the attached drawings and of the following detailed description of those drawings and the presently preferred embodiments of the invention.

Brief Description of the Drawings

Figure 1 illustrates a computer configuration on which the method of the invention runs.

Figure 2 is a flow diagram showing the steps of the method of the invention.

Detailed Description of the Invention

Referring to Figure 1, which illustrates a representative computer configuration on which the method of the invention runs, it can be seen that there are two computer systems 110 and 120. The first computer system 110 is running a file server operating system (such as Novell NetWare®). Computer system 110 includes computer 112 connected

to network 101 through interface 111 (and its associated software), and mass storage device 114 connected through controller 113 (and its associated software). These represent the standard components of a network file server. In the case of NetWare, computer 112 is generally a PC-compatible computer based on an Intel 386 or 486 processor, network 101 can be an ethernet (so that interface 111 is an ethernet interface), and mass storage device 114 is an SCSI or IDE magnetic disk connected through an appropriate controller 113. Computer 122 would also be a PC-compatible computer, so that it could also run the same NetWare file server operating system as computer 112. Network 101 could also be implemented as a token ring, Arcnet, or any other network technology, such network technology being known to those skilled in the art.

The mass storage devices of the invention should not be viewed as limited to magnetic disk drives, but can also be implemented using optical discs, magnetic tape drives, or any other medium capable

of handling the read and write requests of the particular computer system.

Added to the standard network file server to support the method of this invention are a backup computer system 120 and a means 102 for communicating between computer system 110 and computer system 120.

Computer system 120 has components similar to computer system 110. Computer system 120 can be connected to network 101 through interface 121, although it is not necessary for computer system 120 to actually be connected to network 101 during normal operation. Computer 122 is connected to interface 121 and to mass storage device 124 through controller 123.

While it is not necessary for computer system 120 to have identical components to computer system 110, in many cases that will be the case. In other cases, computer system 120 may be an older, slower system previously used as a file server but replaced with computer system 110. All that is required of computer system 120 is that it be

capable of running the file server operating system in case of the failure of computer system 110, and that its mass storage device 124 be of sufficient capacity to hold the data mirrored from mass storage device 114.

Communications means 102 provides a link between computer systems 110 and 120. Computer 112 is connected to communications means 102 through attachment 115, and computer 122 is connected to communications means 102 through attachment 125. Communications means 102 can be implemented using a variety of techniques, well-known to those skilled in the art. In the preferred embodiment, a high-speed serial point-to-point link is used. An alternative would be to use the serial communications ports of computers 112 and 122, programmed to run at a high data rate, or the parallel interfaces of computers 112 and 122. Another alternative is for communications means 102 to be a virtual circuit or channel carried on network 101. In this latter case, communications means 102 would really be network 101, attachment

115 would really be interface 111, and attachment 125 would really be interface 121.

It is important that communication means 102 provide data transfer at rates comparable to the data rate of mass storage device 124 so that it does not limit the performance of the system. The method of this invention is not dependant on the particular implementation of communications means 102.

Figure 2 is a flow diagram showing the steps of the method of the invention. In step 201, a special program -- the mass storage access program -- is run on computer system 120. The mass storage access program receives commands from computer system 110 over communications means 102. Based on those commands, the mass storage access program accesses mass storage device 124 to perform the operation specified in the command received from computer system 110. The results of the accessing of mass storage device 124 is returned to computer system 110 over communications means 102.

The mass storage access program can be enhanced to provide a cache of data on mass storage device 124. The implementation of such a cache function is well-known in the art, consisting of keeping a copy of the most recently accessed information of mass storage device 124 in the memory of computer 122. When a read command is received, it is not necessary to access mass storage device 124 if a copy of the data is in the cache. Since, in the preferred embodiment, computer 122 has a large memory (it must be large enough to run the file server operating system) and the mass storage access program is quite small, there is a large amount of memory available for the cache. This means that many entries will be in the cache, and the chance of finding a block being read in the cache is higher than would be normal for a similar cache in a file server operating system.

In step 202, coincidentally with the running of the mass storage access program on computer system 120, another program -- the mass storage emulator -- is installed on computer system 110. The mass

storage emulator takes mass storage requests from the file server operating system running on computer system 110 and sends them as commands over communications means 102 to computer system 120, where they are processed by the mass storage access program, as discussed above.

When results from a command are received from the mass storage access program over communications means 102 by the mass storage emulator, they are returned to the file server operating system, much as the result of a normal mass storage request would be returned. In this way, the mass storage access program and the mass storage emulator cooperate to make it appear to the file server operating system that mass storage device 124 is directly connected to computer 112 on computer system 110.

In the preferred embodiment of this invention, the mass storage access program is a conventional program running under the disk operating system of personal computer 122. The disk storage emulator is a NetWare Loadable Module (NLM), much like the

device driver for a disk drive. Copies of the source code for the mass storage access program and the mass storage emulator are given in the microfiche appendix.

In step 203, mirroring of data is initiated. When data is being mirrored on two or more mass storage devices, whenever data is to be written it is written to all mass storage devices taking part in the mirroring, at the same location on each mass storage device. (The location may be relative to the start of the mass storage device, or to the start of a partition or contiguous portion of the mass storage device, as appropriate to the way the mass storage device has been formatted and is being used.) Data can be read from any mass storage device taking part in the mirroring, since each mass storage device contains identical data.

Mirroring may be an integral function of the file server operating system, so that no special program is necessary for implementing disk mirroring as part of the method of this invention. Step 203 only requires the activation or starting

of mirroring on the part of the file server operating system. This is the case in the preferred embodiment of the invention, operating with NetWare and using the mirroring facilities of that file server operating system.

If the file server operating system does not provide mirroring, a separate mirroring module will have to be implemented. Such a mirroring module, whose implementation should be obvious to one skilled in the art, will take each write request and pass it to the driver for each mass storage device taking part in the mirroring. For mass storage device 124 on computer system 120, the driver will be the mass storage emulator, discussed above. When successful completion of the write request has been received from all mass storage devices taking part in the mirroring, the mirroring module will indicate successful completion to the file server operating system.

For read requests, the mirroring module can direct the read request to any of the mass storage devices, since all contain identical data.

Generally, the read request will be directed to the mass storage device which is first available to handle the request.

As part of the initiating of mirroring, it is necessary to assure that each mass storage device taking part in mirroring has the same contents at the start of mirroring. This can be done by designating one of the mass storage devices as the master, and making a copy of the master mass storage device's data to all other mass storage devices taking part in the mirroring. An alternative approach is to have a timestamp indicating when the last change was made to the data on a mass storage device. If the timestamp on a mass storage device is the same as the timestamp on the master mass storage device, it will not be necessary to make a new copy of the data.

At step 204, the method of this invention waits until a failure of file server computer system 110 is detected. Such a failure could come from the failure of either hardware (such as computer 112 or mass storage device 114) or software (such as the

file server operating system). Although means for automatically detecting such a failure may be used, in the preferred embodiment such failure is detected by a system operator or workstation user by noticing that file server requests are no longer being handled by computer system 110. It is not difficult for a user to determine there is a problem with file server computer system 110; in most cases, a user workstation will stop working and "hang" while it waits for a file server request that will never be honored.

In step 205, when a failure of computer system 110 has been detected, if computer system 120 is not currently connected to network 101 through interface 121, a connection to the network 101 is made. This can be done either by activating interface 121 or physically connecting interface 121 to network 101, as appropriate.

In step 206, when computer system 120 has been connected to network 101, a file server operating system is loaded into computer 122 and executed, making computer system 120 a file server computer

system. New file server computer system 120 now responds to requests received from network 101 as failed file server computer system 110 did before its failure. The file server operating system executing on computer 122 accesses mass storage device 124 to respond to the requests.

Note that because mass storage device 124 received data through the mass storage emulator and mass storage access program while file server computer system 110 was operating, mass storage device 124 contains a copy of the data stored on mass storage device 114 prior to the failure of computer system 120. (Because of timing, the last few write operations may not have occurred on all mass storage devices taking part in mirroring, but the file server operating system is capable of handling these small differences.) Because a copy of the mass storage data of failed file server computer system 110 is immediately available to new file server computer system 120, the time necessary to recover from a file server failure is minimal.

When the fault that caused the failure of computer system 120 has been corrected, fault-tolerant operation can be restored. Depending on the relative capabilities of computer systems 110 and 120, one of two techniques can be employed. Both involve the same method steps as were discussed above.

If the two computer systems have components of similar speed and capacity, there is no reason not to continue using computer system 120 as the file server computer. In this case, computer system 110 can now be treated as the backup computer system. The mass storage access program is run on computer system 110, the mass storage emulator is installed on computer system 120, and mirroring is initiated on the file server operating system running on computer system 120. As part of the initiating of mirroring, any data written to mass storage device 124 during the time computer system 110 was not available is now copied to mass storage device 114 though the mass storage emulator, communications mean 102, and the mass storage access program.

Alternatively, if computer system 120 is less capable than computer system 110, it will be desirable to make computer system 110 the file server computer system when the failure has been corrected. To accomplish this, two approaches are possible. In the first approach, computer system 110 is brought up as the backup computer system, running the mass storage access program, as discussed above. When mass storage device 114 contains a copy of the data on mass storage device 124, computer system 110 can be restarted as the file server (running the file server operating system) and computer system 120 can be restarted as the backup computer in accordance with the method discussed above.

Alternatively, when the failure of computer system 110 has been corrected, computer system 120 can be restarted as backup computer system, running the mass storage access program, and computer system 110 can be restarted as the file server computer, running the file server operating system and the mass storage emulator. When mirroring is

initiated, it will be determined by the timestamps stored on each of mass storage devices 114 and 124 that the data on mass storage device 114 is out of date. The file server operating system will read the data on mass storage device 124 (though the mass storage emulator, communications means 102, and the mass storage access program). It will also copy the data from mass storage device 124 to mass storage device 114 until they contain identical data.

It is to be understood that the above described embodiments are merely illustrative of numerous and varied other embodiments which may constitute applications of the principles of the invention. Such other embodiments may be readily devised by those skilled in the art without departing from the spirit or scope of this invention and it is our intent they be deemed within the scope of our invention.

Claims

We claim:

1. A method for rapid recovery from a network file server failure, operating on a computer configuration that includes:

a first computer system, comprising:

(a) a first computer executing a file server operating system adapted to respond to requests received from a network,

(b) a first interface connecting said first computer to said network, and

(c) a first mass storage device connected to said first computer;

a second computer system, comprising:

(a) a second computer capable of executing said file server operating system,

(b) a second interface capable of connecting said second computer to said network, and

(c) a second mass storage device connected to said second computer;

and means for communicating between said first computer system and said second computer system, the recovery method of the invention comprising:

(A) running a mass storage access program on said second computer, said mass storage access program receiving commands from said first computer over said communicating means, accessing said second mass storage device as specified by said commands, and returning said commands' results to said first computer over said communicating means;

(B) installing a mass storage emulator on said first computer for use by said file server operating system, said mass storage emulator taking mass storage requests from said file server operating system, sending commands to said second computer system over said communicating means, and returning results of said commands received over said communicating means from said

second computer to said file server operating system;

(C) initiating mirroring of data by writing data both to said first mass storage device and through said mass storage emulator and said mass storage access program to said second mass storage device;

(D) when a failure of said first computer system is detected, stopping said mass storage access program on said second computer; and then

(E) if said second computer is not currently connected to said network, connecting said second computer to said network through said second interface; and then

(F) executing said file server operating system on said second computer, said file server operating system responding to requests received from said network and accessing data stored on said second mass storage device.

2. A method as in claim 1, wherein said first computer system and said second computer system are each PC-compatible computers.

3. A method as in claim 2 wherein said file server operating system is Novell NetWare.

4. A method as in claim 1, wherein said network is an ethernet.

5. A method as in claim 1, wherein said network is a token ring.

6. A method as in claim 1, wherein said first mass storage device is a magnetic disk.

7. A method as in claim 1, wherein said second mass storage device is a magnetic disk.

8. A method as in claim 1, wherein said means for communicating between said first computer system and said second computer system is a high-speed serial point-to-point link.

9. A method as in claim 1, wherein said means for communicating between said first computer system and said second computer system uses the serial communications ports of said first computer and said second computer.

10. A method as in claim 1, wherein said means for communicating between said first computer system and said second computer system uses the parallel interfaces of said first computer and said second computer.

11. A method as in claim 1, wherein said means for communicating between said first computer system and said second computer system is said network.

12. A method as in claim 1, wherein said mass storage access program provides a cache of data on said second mass storage device.

13. A method as in claim 1, wherein said mass storage access program and said mass storage emulator makes said second mass storage device of said second computer system look like another mass storage device on said first computer system.

14. A method as in claim 1, wherein said mirroring of data is performed by said file server operating system.

15. A method as in claim 1, wherein said mirroring of data is performed by a mirroring module.

16. A method as in claim 1, wherein said method is also used for restoration of fault-tolerant operation.

17. A method as in claim 16, wherein said second computer system becomes a file server computer system and said first computer system becomes a backup computer system.

18. A method as in claim 16, wherein said first computer system again becomes a file server computer and said second computer system becomes a backup computer system.

19. A method for rapid recovery from a network file server failure, the method operating on a computer system that includes:

a first computer system, comprising:

(a) a first computer capable of executing a file server operating system adapted to respond to requests received from a network,

(b) a first interface adapted to connect said first computer to said network, and

(c) a first mass storage device capable of being connected to said first computer;

a second computer system, comprising:

(a) a second computer capable of executing said file server operating system,

(b) a second interface capable of connecting said second computer to said network, and

(c) a second mass storage device capable of being connected to said second computer;

and means for communicating between said first computer system and said second computer system, the recovery method of the invention comprising:

(A) running a mass storage access program on said second computer, said mass storage access program being capable of receiving commands from said first computer over said communicating means, accessing said second mass storage device as specified by said commands, and returning said commands'

results to said first computer over said communicating means;

(B) installing a mass storage emulator on said first computer for use by said file server operating system, said mass storage emulator taking mass storage requests from said file server operating system, sending commands to said second computer system over said communicating means, and returning results of said commands received over said communicating means from said second computer to said file server operating system;

(C) initiating mirroring of data by writing data both to said first mass storage device and through said mass storage emulator and said mass storage access program to said second mass storage device;

(D) when a failure of said first computer system is detected, stopping said mass storage access program on said second computer;

(E) connecting said second computer to said network through said second interface as necessary;

(F) executing said file server operating system on said second computer, said file server operating system being capable of responding to requests received from said network and accessing data stored on said second mass storage device.

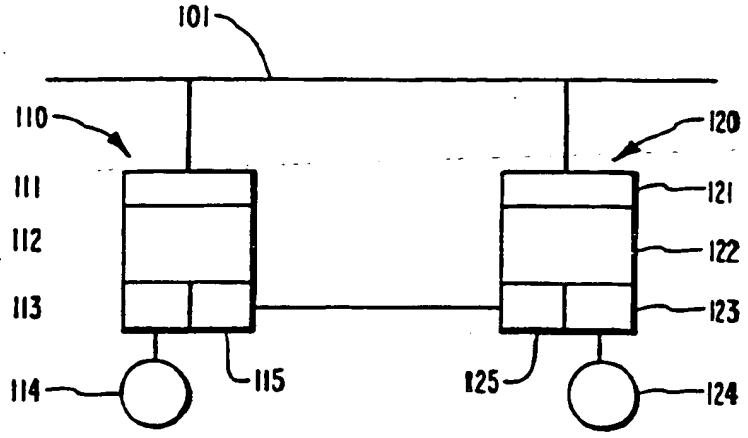
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FIG. 1

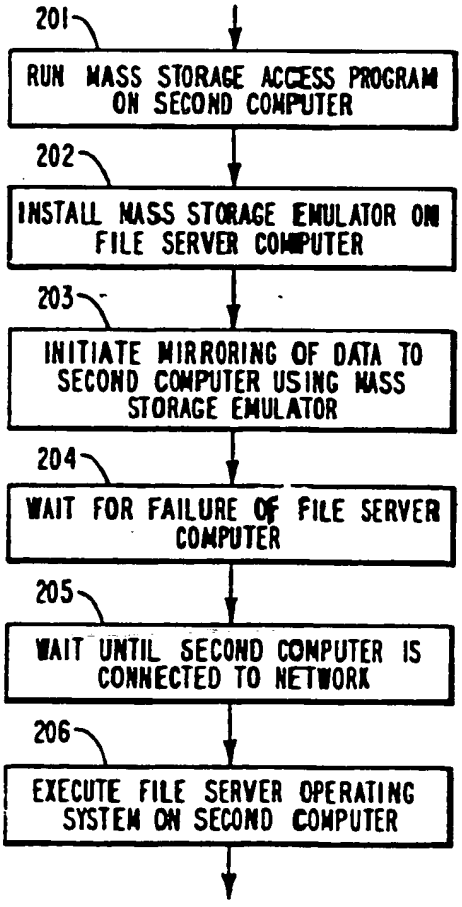
201
RUN MASS STORAGE ACCESS PROGRAM ON SECOND COMPUTER
202
INSTALL MASS STORAGE EMULATOR ON FILE SERVER COMPUTER
203
INITIATE MIRRORING OF DATA TO SECOND COMPUTER USING MASS STORAGE EMULATOR
204
WAIT FOR FAILURE OF FILE SERVER COMPUTER
205
WAIT UNTIL SECOND COMPUTER IS CONNECTED TO NETWORK
206
EXECUTE FILE SERVER OPERATING SYSTEM ON SECOND COMPUTER

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/07046

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :G06F 11/20,16
US CL :395/575,600; 371/9.1,11.3

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 395/575,600; 371/9.1,11.3

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PROQUEST (IEEE PERIODICALS)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y,P	US, A, 5,307,481 (Shimazaki et al) 26 April 1994 see Figures 1-3 and col. 2, lines 15-30; col. 5, line 22 - col. 8, line 19	1-19
Y	US, A, 5,157,663 (Major et al) 20 October 1992 see Figure 1; col. 2, line 42 - col. 3, line 32; col. 3, line 67 - col. 6, line 16; col. 9, lines 15 - 36	1-19
Y,P	US, A, 5,235,700 (Alaiwan et al) 10 August 1993 see Figure 1 and col. 4, line - col. 6, line 35	1-19
A	US, A, 5,079,740 (Patel et al) 07 January 1992, see Figure 1 and col. 1, line 46 - col. 2, line 44.	1-19

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search	Date of mailing of the international search report
22 August 1994	26 SEP 1994
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	Authorized officer Paul Harrity
Facsimile No. NOT APPLICABLE	Telephone No. (703) 305-9677

Form PCT/ISA/210 (second sheet)(July 1992)*

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/07046

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 4,823,256 (Bishop et al) 18 April 1989, see Figures 1 and 3b, col. 2, line 39 - col. 3, line 44.	1-19
A, P	US, A, 5,295,258 (Jewett et al) 15 March 1994, see col. 2, line 38 - col. 4, line 61.	1-19